Biomass gasification: challenges, processes, and obstacles

- Laurent Van de steene -

steene@cirad.fr

BioWooEB

Biomass Wood Energy Bioproducts

LC Biomass to Energy

Biochemical process
(wet)

Hydrolysis /
Fermentation

**Thermochemical process
(dry)**

**Pyroysis
Torrefaction**

Gasification

Combustion

**Cellulosic
ethanol**

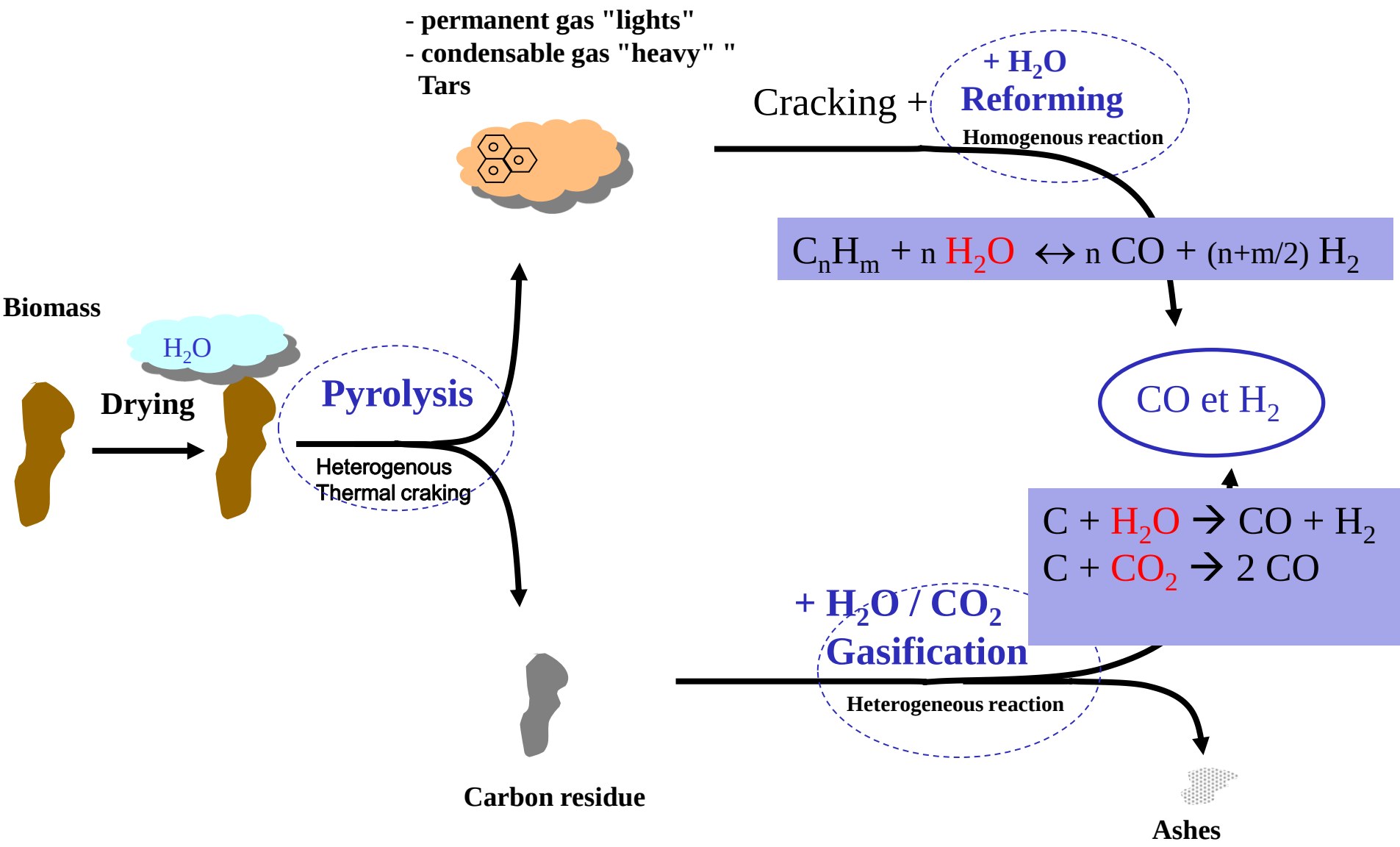
Biofuels
"2nd génération"

**Diesel
SNG**

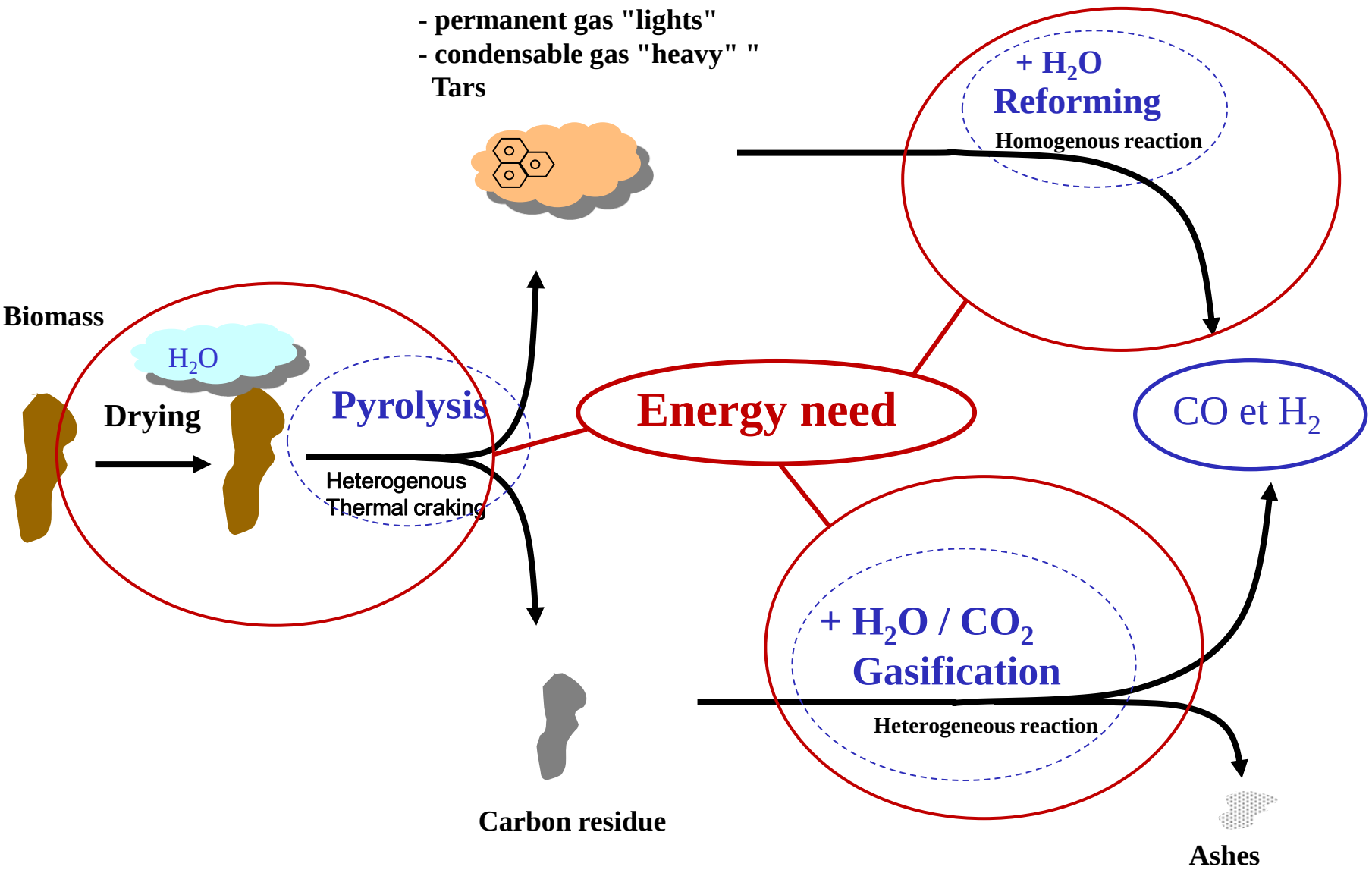
Gas

Electricity

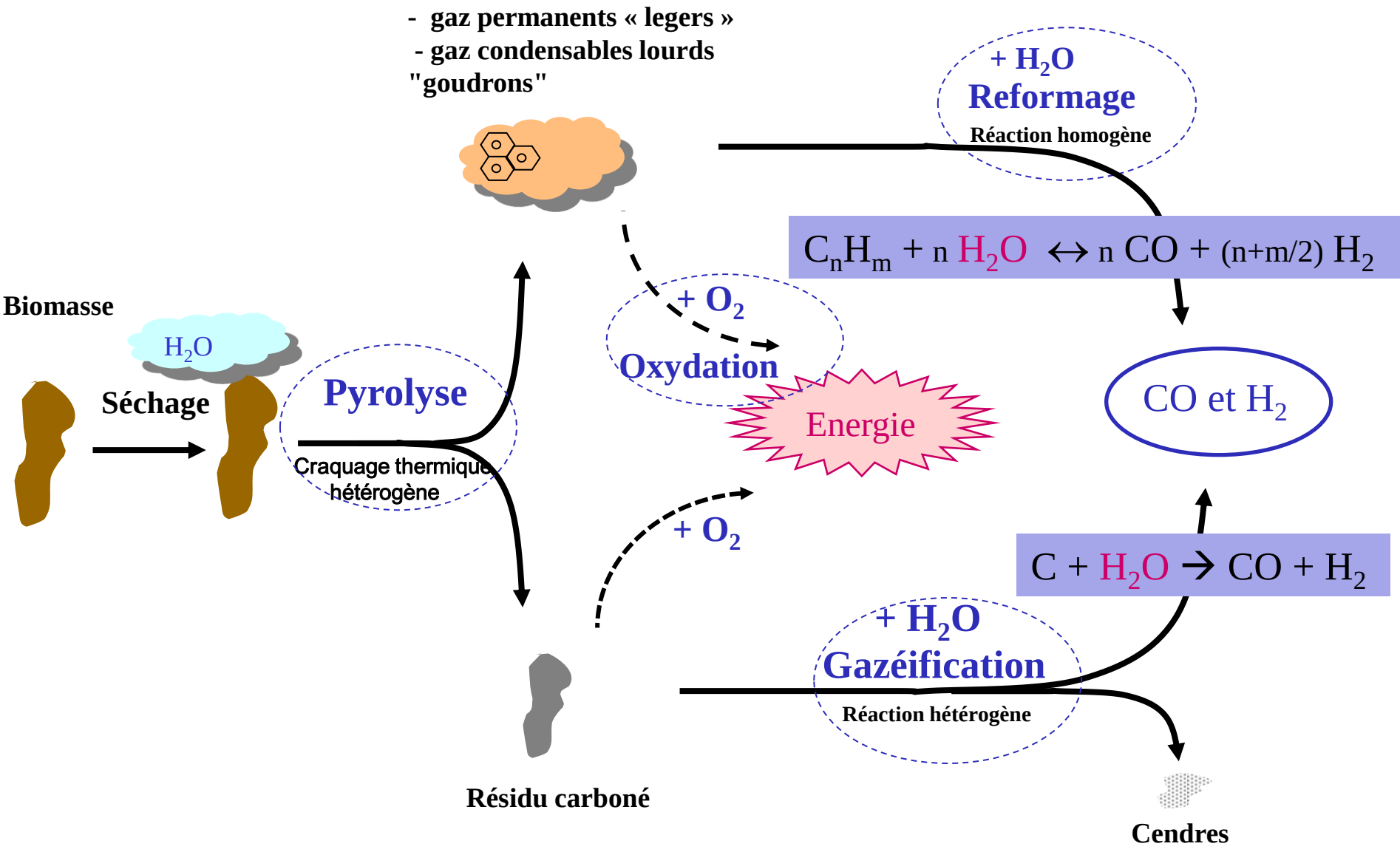
Gasification



Gasification



Gasification



Electricity and heat production

Fuel gas

Integrated Gasification Combined Cycle (IGCC)
~ 50 %

Burner

Gas engine

Gas turbine

Steam turbine

~ 80 %

~ 30 %

20 %

~ 30 %

Heat (Gas-industry)

Electricity (cogeneration)

Biofuel production

Fuel gas

Cleaning / conditionning

Syngas (CO and H_2)

BTL

GTL

Synthesis

SNG

Diesel

Methanol

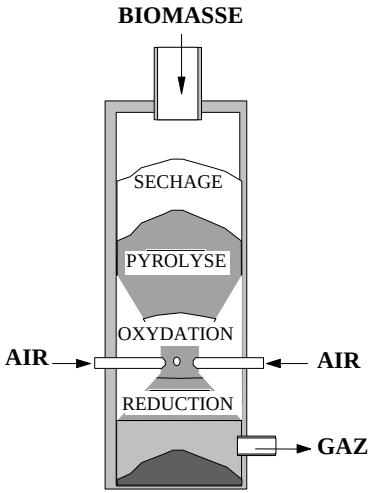
Ethanol

DME

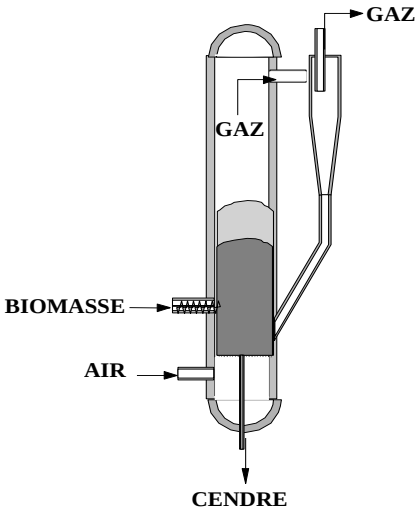
by-products
(pharma, cosm,…)

Gasification reactors

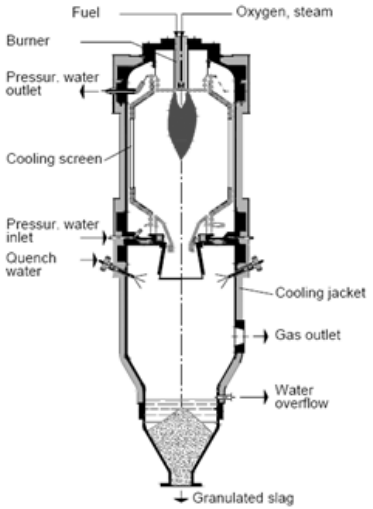
Fixed beds



Fluidised beds



Entrained flow reactors



- Updraft (counter-current)
- Downdraft (co-current)
- Staged

- Bubling
- Circulating
- Double

8

cirad

- Gas composition -

	Downdraft staged (Xylowatt)	Updraft (B&W Volund)	Fluidised bed (F&W)	Double fluidised bed (Repotech)	Entrained flow (Carbo-V)
H_2 ($\%_{vol,sec}$)	16	18	11	39	36
CO ($\%_{vol,sec}$)	19	24	17	22	38
CH_4 ($\%_{vol,sec}$)	2	5	6	11	0.4
Tars (g/Nm^3)	0,02-0.04	60-80	1-4	2-5	0
HV* (kJ/Nm^3)	~ 5000	~ 6000	~ 5000	~ 11000	~ 12000

* Heating value : Natural gas : 35000 kJ/Nm^3

Some examples

Fixed beds : downdraft

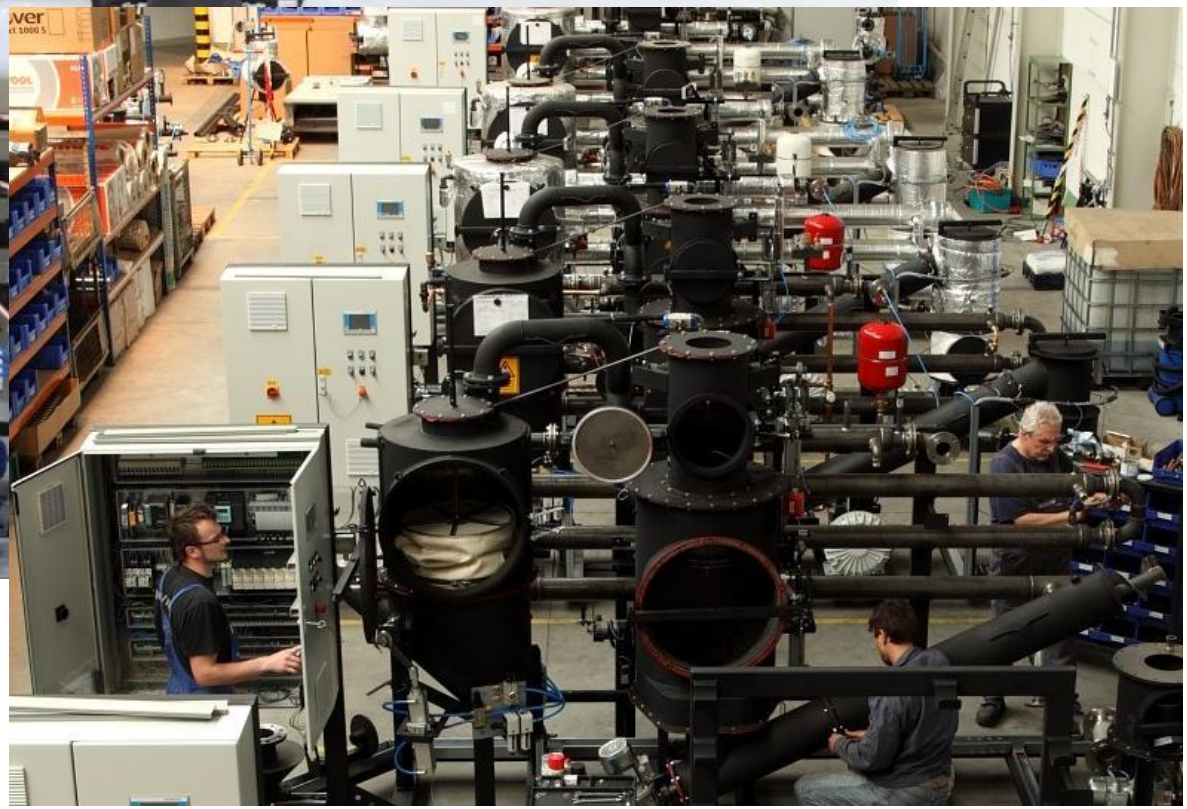
Ankur, Ind

- **15 à 2000 kg/h biomass –**

Fixed beds : downdraft

Spanner, ALL

30-40 KWel
"Wood chips"



Fixed beds : downdraft

All Power Lab, EU

GEK
- 10-20 KWel –
Wood chips

"open source"

Fixed beds : downdraft

All Power Lab, EU

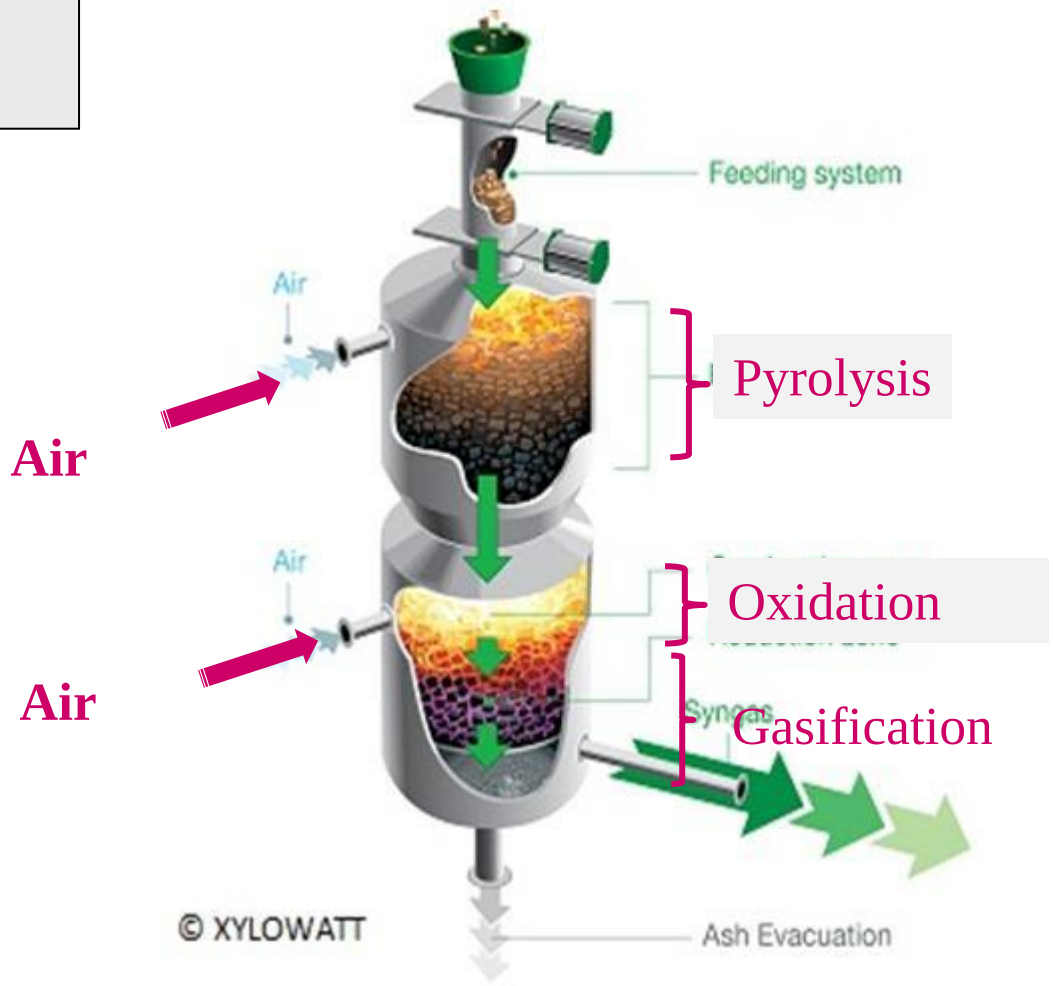
Power Pallets
- 10-20 KWel -
Wood chips

" Integrated solution "

Fixed beds : staged downdraft

Xylowatt, Bel

NOTAR
- 300 KWel -
Wood chips

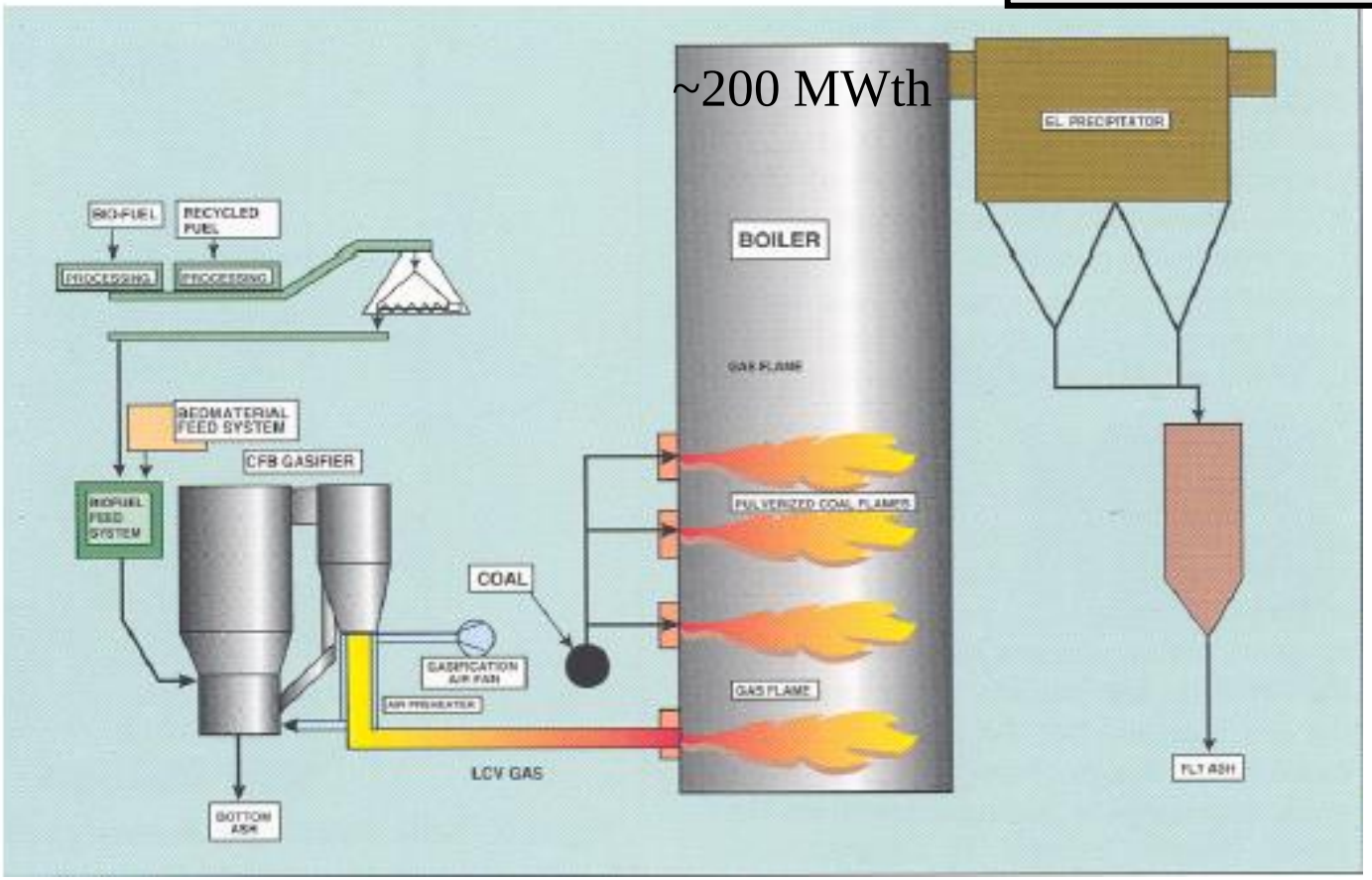


Fixed beds : staged downdraft

Fluidised beds : circulating

Lathi, F&W, Finlande

- 50-75 MWth
- Cogénération
- co-combustion déchet
- Depuis 1998

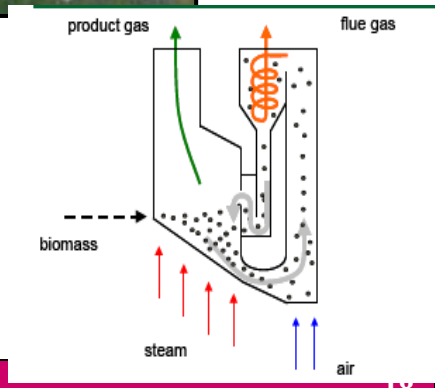


Fluidised beds : double

Gussing, Repotec, Autriche

8 MW : 2 MWel / 4,5 MWth

Plaquettes forestières



Fluidised beds : double

Fluidised beds : double

Technological barriers (and economical)

- Gas quality (tars, inorganics, aerosols, ….)
- Biomass supplying (from land to reactor)

Technological barriers (and economical)

→ Gas quality (tars, inorganics, aerosols, ….)

- Constraints related to applications -

Applications	**Tars** Mg/Nm^3	**Particles** Mg/Nm^3	**Alkalines** Mg/Nm^3	**Ammonia** (Mg/Nm^3)	**Chlorine** Mg/Nm^3	**Sulphur** Mg/Nm^3
Gas engine	< 50	<50	<1	<50	<10	<100
Gas turbine	< 5	< 30	~ ppmv			
Synthesis Fisher Tropsch / Methanol	< 1	< 0.02	~ ppmv			
Fuel cells	< 1	~ ppmv				

Technological barriers (and economical)

→ Gas quality (tars, inorganics, aerosols, ….)

- Very low tolerance limits (from ppm to few mg/Nm3)
- Thermal or catalytic tar craking
- "In situ" or post traitement…

→ Biomass supplying (from land to reactor)

Requirements regarding fuel ?

Process	Downdraft	Updraft	Fluidised bed	Entrained flow
Granulometry (mm)	20-100	5-100	1-10	< 1
Moisture (%wb)	< 15-20	< 50	< 40	< 15
Ashes (% db)	< 5	< 15	< 20	< 20
Melting point ashes (°C)	> 1250	> 1000	> 1000	> 1250
Density (kg/m^3)	> 500	> 400	> 100	> 400

Technological barriers (and economical)

→ Gas quality (tars, inorganics, aerosols, ….)

- Very low tolerance limits (from ppm to few mg/Nm3)
- Thermal or catalytic tar cracking
- "In situ" or post treatment…

→ Biomass supplying (from land to reactor)

- Resource scattered, transport
- Preparation cost (grinding), feeding (under pressure)
- Biomass variability
- Torrefaction
- Flash pyrolysis

→ Conditioning process

Research on going

- Liquid or solid fuel
- homogenization
- energy densification

How ?

Particles
- Classic filtration (cyclone, baghouse)
- Hot filtration (ceramic filters)
- Electrostatic filter, Scrubber.

tars
- Wet scrubber
- Electrostatic "Collector"
- Catalytique cracking (~ 800 °C)

non metallic : Dolomie ($CaMg(CO3)2$) , Zeolite, Calcite. (ex : VTT, Fin)

metallic : Ni, Fe,... (ex : RFTC : Reverse-flow tar converter, BTG, H)

- Thermal cracking (>1200 °C)

Alcalins (Na, K, P, …), Nitrogenous compounds

Conclusion: biomass gasification

Electricity

Processes are on operation but industrial demonstration for electricity production from biomass need to be confirmed

- Investistors concerned (but financial and technological risks still high)
- Need for performance guarantees (7000 h/an)
- Constructors specialization ("mass production")

gas (for industry)

Positive context but to be demonstrated

- High efficiency (80 %)
- Many industries concerned

Conclusion: biomass gasification

Biofuels

- ✓ Ligno-cellulosic biomass: potential "in theory" but availability questionable
- ✓ High performance biofuels "BtL" : quality and yield

➡ Yields :

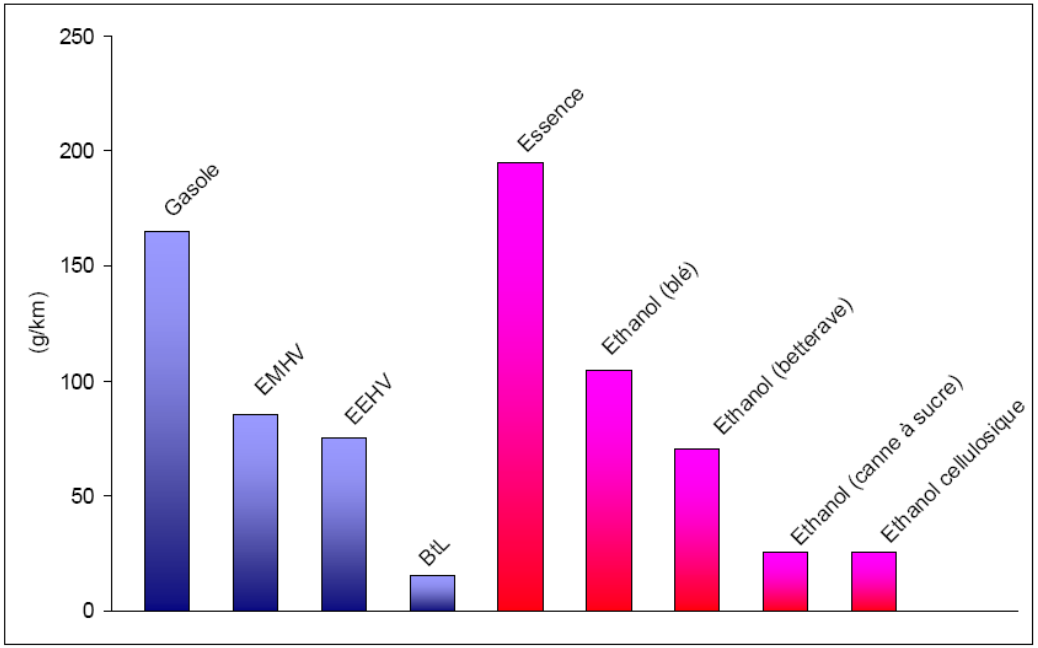
Gasification : 1,5 à 3,5 toe/ha
Ethanol (1ere gene) : 0,65 à 0,85 toe/ha
VOME : 0,7 à 0,95 toe/ha

Conclusion: biomass gasification

Biofuels

- ✓ Ligno-cellulosic biomass: potential "in theory" but availability questionable
- ✓ High performance biofuels "BtL" : quality and yield
- ✓ Good environmental evaluation regarding CO_2 "from well to wheel"

CO_2 emission (g per km)



Source : CEA

Conclusion: biomass gasification

Biofuels

✓ Ligno-cellulosic biomass: potential "in theory" but availability questionable

✓ High performance biofuels "BtL" : quality and yield

✓ Good environmental evaluation regarding CO_2 "from well to wheel"

→ Technologies not matures : production costs too high, upscaling complex (biomass supplying), very high investments.

✓ **High concerns for Synthetic Naturel Gas**

To be demonstrated at industrial scale !

✓ **Perspectives 2020 ??**

CIRAD
- laboratories -
- Pilot test Plateform -

Phycico-chemical laboratories

Thermochemical lab

Staged gasification pilot 75 KWth

Fash Pyrolysis reactor (fluidised bed)

Continuous fixed bed reactor

Torrefaction reactor